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For full solutions to the practice problems, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

1. (a) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$, this is a hydrocarbon combustion reaction

(b) $P_4(s) + 4I_2(s) \rightarrow 2P_2I_4(s)$, this is a formation reaction

(c) $Cl_2(g) + 2CsBr(aq) \rightarrow Br_2(\ell) + 2CsCl(aq)$, this is a single replacement reaction

(d) $3Ba(ClO_3)_2(aq) + 2Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NaClO_3(aq)$, this is a double replacement reaction

(e) $2Li_3N(s) \rightarrow 6Li(s) + N_2(g)$, this is a decomposition reaction.

(f) $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$, this reaction may be classed as a decomposition

2. (a) $2C_4H_{10}(g) + 13O_2(g) \rightarrow 10H_2O(g) + 8CO_2(g)$

(b) $Zn(s) + Pb(NO_3)_2 \rightarrow Pb(s) + Zn(NO_3)_2(aq)$

(c) $8Mg(s) + S_8(s) \rightarrow 8MgS(s)$

(d) $Sr(OH)_2(aq) + H_2SO_4(aq) \rightarrow SrSO_2(aq) + 2H_2O(\ell)$

(e) $2LiN_3(s) \rightarrow 2Li(s) + 3N_2(g)$

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1. (a) $Cl_2(g) + 2Br^-(aq) \rightarrow Br_2(\ell) + 2Cl^-(aq)$

(b) $Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

(c) $2Al(s) + 3Cu^{2+}(aq) \rightarrow 3Cu(s) + 2Al^{3+}(aq)$

(d) $Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$

(e) $H_2(g) + 2Na^+(aq) \rightarrow 2Na(s) + 2H^+(aq)$

2. (a) $3Ba^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$

(b) $Sr^{2+}(aq) + SO_4^{2-}(aq) \rightarrow SrSO_4(s)$

(c) $2Al^{3+}(aq) + 3Cr_2O_7^{2-}(aq) \rightarrow Al_2(Cr_2O_7)_3(s)$

(d) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$

(e) $Mg^{2+}(aq) + 2OH(aq) \rightarrow Mg(OH)_2(s)$

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Q1. (a) dichromate ion

(b) copper(II) ion

(c) sodium ion

Q2. (a) $SO_4^{2-}(aq)$, $OH^-(aq)$, $PO_4^{3-}(aq)$, $SO_3^{2-}(aq)$, or $CO_3^{2-}(aq)$.

(b) $CH_3COO^-(aq)$, $Cl^-(aq)$, $Br^-(aq)$, or $I^-(aq)$ will precipitate aqueous silver ions, but not aqueous calcium ions.

(c) Flame colour: the solution containing calcium ions will produce a red flame, while the solution containing silver ions will not.

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1. Spectator ions are aqueous ions that remain unchanged when the reaction is over. When forming ionic

compounds with other ions, spectator ions form compounds with high solubility.

2. **(a)** $3Sn^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Sn_3(PO_4)_2(s)$

   (b) $Ni^{2+}(aq) + CO_3^{2-}(aq) \rightarrow NiCO_3(s)$

   (c) $2Cr^{3+}(aq) + 3S^{2-}(aq) \rightarrow Cr_2S_3(s)$

3. **(a)** The spectator ions are $Cl^-(aq)$ and $K^+(aq)$.

   (b) The spectator ions are $Cl^-(aq)$ and $Na^+(aq)$.

   (c) The spectator ions are $SO_4^{2-}(aq)$ and $NH_4^+(aq)$.

4. The precipitate that will form is copper(II) carbonate, $CuCO_3(s)$. The net ionic equation is $Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$. The spectator ions are $SO_4^{2-}(aq)$ and $Na^+(aq)$.

5. **(a)** $Ba(NO_3)_2(aq)^* + Na_3PO_4(aq)^{**}$

   (b) $Mg(NO_3)_2(aq)^* + NaOH(aq)^{**}$

   (c) $Al(NO_3)_3(aq)^* + Na_2Cr_2O_7(aq)^{**}$

   *the cation can also combine with ClO_4^- or ClO_3^-

   **the anion can combine with any group 1 ion, H^+ or NH_4^+

6. Qualitative analysis only determines whether or not a particular substance is present. Quantitative analysis allows the determination of the amount of a particular substance.

7. No. Qualitative analysis will only provide the identity of ions present. Qualitative analysis such as solution colour, flame colour, and selective precipitation will only tell you if an ion is present or not. More complicated gravimetric procedures (that will be described in the remaining part of this chapter, as well as in Chapter 8) are needed to determine the amount of each ion present.

8. (a) $CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq)$

$H_2CO_3(aq) + Ca(OH)_2(aq) \rightarrow 2HOH(\ell) + CaCO_3(s)$

(b) The first reaction can be classified as a formation reaction, while the second is classified as a double-replacement reaction.

(c) This is a qualitative test, as it only tells you if carbon dioxide is present, not how much is present.

9. (a) $Pb^{2+}(aq)$, $PbCl_2(s)$

(b) $Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$

10. (a) $Na_2SO_4(aq)$ (any group 1 sulfate)

(b) NaCl(aq), NaBr(aq), NaI(aq) (any group 1 halide)

(c) To the solution, add $Na_2SO_4(aq)$ until no more precipitate forms.
Remove the $PbSO_4(s)$ precipitate by filtration and dispose of the precipitate appropriately.

To the filtrate, add NaCl(aq) until no more precipitate forms. Remove the CuCl(s) precipitate by filtration and dispose of the precipitate appropriately.

To the filtrate, add NaOH(aq) until no more precipitate forms. Remove the $Eu(OH)_3(s)$ precipitate by filtration and dispose of the precipitate appropriately.

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Q3. (a) 2 mol $H_2(g)$: 1 mol $O_2(g)$: 2 mol $H_2O(\ell)$

(b) 1 mol $O_2(g)$: 2 mol $H_2O(\ell)$

(c) 2 mol $H_2(g)$: 1 mol $O_2(g)$

Q4. (a) 2 mol $C_2H_6(g)$: 7 mol $O_2(g)$: 4 mol $CO_2(g)$: 6 mol $H_2O(g)$

(b) 1 mol $C_2H_6(g)$: 2 mol $CO_2(g)$

(c) 2 mol $C_2H_6(g)$: 7 mol $O_2(g)$

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3. (a) 2 mol $AgNO_3(aq)$: 1 mol $Na_2CrO_4(aq)$: 1 mol $Ag_2CrO_4(s)$: 2 mol $NaNO_3(aq)$

(b) 2 mol $AgNO_3(aq)$: 1 mol $Ag_2CrO_4(s)$

(c) 0.25 mol

4. (a) 2 mol $NH_3(g)$:1 mol $CO_2(g)$:1 mol $NH_2CONH_2(s)$: 1 mol $H_2O(g)$

(b) 2.60 mol

(c) 6.0 mol

5. (a) 2 mol $NH_3(g)$:1 mol $H_2SO_4(aq)$: 1 mol $(NH_4)_2SO_4(s)$

(b) 40 000 mol or 40 kmol

(c) 1.64 mol

6. (a) 1 mol $Xe(g)$:2 mol $F_2(g)$:1 mol $XeF_4(s)$

(b) 4.70 mol

(c) 24.4 mmol or 0.0244 mol

7. (a) 2 mol $N_2(g)$: 1 mol $O_2(g)$: 2 mol $N_2O(g)$ and 1 mol $N_2(g)$: 2 mol $O_2(g)$: 2 mol $NO_2(g)$

(b) 0.0468 mol

(c) 187 mmol or 0.187 mol

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Q5. The equation used is $n = \frac{m}{M}$, where n is the number of moles of reactant or product, m is the mass and M is the molar mass.

Q6. 0.72 g CuO(s) is produced

Complete Solution

Using equations:

$n = 0.0090$ mol CuO(s)

$M = 79.55$ g/mol CuO(s)

$m = ?$

$$n = \frac{m}{M}$$

$$m = nM$$

$$= (0.0090 \text{ mol CuO(s)})(79.55 \frac{\text{g}}{\text{mol}} \text{ CuO(s)})$$

$$= 0.72 \text{ g CuO(s)}$$

Using dimensional analysis:

$$m_{\text{CuO(s)}} = 0.0090 \cancel{\text{ mol CuO(s)}} \times \frac{79.55 \text{ g}}{\cancel{\text{mol CuO(s)}}}$$

$$= 0.72 \text{ g CuO(s)}$$

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8. 1.3×10^5 g

9. 5.84×10^5 g or 5.84×10^2 kg

10. **(a)** $Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$

(b) 3.39 g

11. 112 g

12. 8.06 g

13. 20.1 g

14. 40.3 g

15. 417 g

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Q7. 0.03 mol NaCl(aq)

Complete Solution

$n_{NaCl(aq)} = c_{NaCl(aq)} \times V_{NaCl(aq)}$

$$= \frac{1 \text{ mol NaCl(aq)}}{\text{L}} \times 0.025 \text{ L}$$

$$= 0.3 \text{ mol NaCl(aq)}$$

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16. 18 mL

17. 12.9 mL

18. (a) $Pb(NO_3)_2(aq) + 2NaI(aq) \rightarrow PbI_2(s) + 2NaNO_3(aq)$

(b) 40.0 mL

(c) 1.15 g

19. (a) 0.33 L

(b) 0.13 L

(c) 0.46 L

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Q8. (a) 2 mol $O_2(g)$:1 mol $N_2O_4(g)$

(b) 2 L $O_2(g)$:1 L $N_2O_4(g)$

(c) If 1 L of $N_2O_4(g)$ is produced, then 2 L of $O_2(g)$ would have been consumed if temperature and pressure remain constant.

(d) 2 L of oxygen will be consumed.

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20. (a) 1 mol $O_2(g)$: 2 mol $H_2O(g)$

(b) 1 mol $H_2(g)$: 1 mol $H_2O(g)$

(c) 20 L

21. 24.0 L

22. 30 L

23. (a) $2A(g) + B(g) \rightarrow C(g)$

(b) $A_4B_2(g)$

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Q9. 74 L

Complete Solution

$P = 100$ kPa
$n = 3.0$ mol $H_2(g)$
$T = 25°C = 298.15$ K
$V = ?$

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$= \frac{(3.0 \text{ mol } H_2(g))\left(\frac{8.314 \text{ L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}}\right)(298.15 \text{ K})}{100 \text{ kPa}}$$

$$= 74 \text{ L}$$

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24. **(a)** 67 L

(b) 0.016 mol

(c) 4.8×10^{-4} mol

25. 0.787 L

26. 5.7×10^{6} L

27. 2.73×10^{-3} g

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1. Qualitative analysis only determines whether or not a particular substance is present. Quantitative analysis allows the determination of the amount of a particular substance.

2. $2KOH(aq) + Cu(NO_3)_2(aq) \rightarrow Cu(OH)_2(s) + 2KNO_3(aq)$

$m = 3.66$ g, $M = 56.11$ g/mol

$m = ?$ g, $M = 97.57$ g/mol

$$m\,Cu(OH)_2 = 3.66\text{ g KOH} \times \frac{1\text{ mol}\cancel{KOH}}{56.11\text{ g}\cancel{KOH}} \times \frac{1\text{ mol}\cancel{Cu(OH)_2}}{2\text{ mol}\cancel{KOH}} \times \frac{97.57\text{ g}\cancel{Cu(OH)_2}}{1\text{ mol}\cancel{Cu(OH)_2}}$$

$$= 3.18\text{ g}$$

3. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

$m = 1.00$ kg $\qquad m = ?$ kg

$m = ?$ kg $\qquad M = 16.05$ g/mol

$M = 44.01$ g/mol $\qquad M = 18.02$ g/mol

$$mCO_2 = 1.00 \text{ kg } \cancel{CH_4} \times \frac{1 \text{ } \cancel{\text{mol } CH_4}}{16.05 \text{ } \cancel{\text{g } CH_4}} \times \frac{1 \text{ } \cancel{\text{mol } CO_2}}{1 \text{ } \cancel{\text{mol } CH_4}} \times \frac{44.01 \text{ } \cancel{\text{g } CO_2}}{1 \text{ } \cancel{\text{mol } CO_2}}$$

$$= 2.74 \text{ kg}$$

$$mH_2O = 1.00 \text{ kg } \cancel{CH_4} \times \frac{1 \text{ } \cancel{\text{mol } CH_4}}{16.05 \text{ } \cancel{\text{g } CH_4}} \times \frac{2 \text{ } \cancel{\text{mol } H_2O}}{1 \text{ } \cancel{\text{mol } CH_4}} \times \frac{18.02 \text{ } \cancel{\text{g } H_2O}}{1 \text{ } \cancel{\text{mol } H_2O}}$$

$$= 2.25 \text{ kg}$$

4. $Fe_2O_3(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2Fe(\ell)$

$m = 28$ kg $\qquad m = ?$ g

$M = 159.70$ g/mol $\qquad M = 55.85$ g/mol

$$mAl = 28 \text{ kg } \cancel{Fe_2O_3} \times \frac{1 \text{ } \cancel{\text{mol } Fe_2O_3}}{159.70 \text{ } \cancel{\text{g } Fe_2O_3}} \times \frac{2 \text{ } \cancel{\text{mol Al}}}{1 \text{ } \cancel{\text{mol } Fe_2O_3}} \times \frac{97.57 \text{ } \cancel{\text{g Al}}}{1 \text{ } \cancel{\text{mol Al}}}$$

$$= 20 \text{ kg}$$

5. $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$

$m = 16.8$ g $\qquad m = ?$ g

$M = 84.01$ g/mol $\qquad M = 105.99$ g/mol

$$mNa_2CO_3 = 16.8 \text{ } \cancel{\text{g } NaHCO_3} \times \frac{1 \text{ } \cancel{\text{mol } NaHCO_3}}{84.01 \text{ } \cancel{\text{g } NaHCO_3}} \times \frac{1 \text{ } \cancel{\text{mol } Na_2CO_3}}{2 \text{ } \cancel{\text{mol } NaHCO_3}} \times \frac{105.99 \text{ } \cancel{\text{g } Na_2CO_3}}{1 \text{ } \cancel{\text{mol } Na_2CO_3}}$$

$$= 10.6 \text{ g}$$

6. $Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

$m = 1.6\ g$ $\quad m = ?\ g$

$M = 65.39\ g/mol$ $\quad M = 169.88\ g/mol$

$$m\text{Ag NO}_3 = 1.6\ \cancel{g\ Zn} \times \frac{1\ \cancel{mol\ Zn}}{65.41\ \cancel{g\ Zn}} \times \frac{2\ \cancel{mol\ AgNO_3}}{\cancel{1\ mol\ Zn}} \times \frac{169.88\ g\ AgNO}{1\ \cancel{mol\ AgNO_3}}$$

$$= 8.3\ g\ AgNO_3$$

7. To the solution that contains $Pb(NO_3)_2(aq)$, add NaI(aq) until no more precipitate forms. Weigh a piece of filter paper, remove the $PbI_2(s)$ by filtration, and allow the precipitate and filter paper to dry overnight. Determine the mass of the filter paper and precipitate, and then subtract the mass of the filter paper to obtain the mass of the precipitate. Use stoichiometry to determine the mass of the $Pb(NO_3)_2(aq)$ in the original solution.

8. There are many different types of spreadsheets students can prepare. Have students e-mail their spreadsheet to you so you can assess each design individually. Have some students present their spreadsheet designs to the class.

9. $Ba(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow BaCO_3(s) + 2NaNO_3(aq)$

$V = 60.0\ mL$ $\quad m = ?\ g$

$c = 0.100\ mol/L$ $\quad M = 105.99\ g/mol$

$$m\ Na_2CO_3 = 0.0600\ L \times \frac{0.100\ \cancel{mol\ Ba(NO_3)_2}}{L} \times \frac{1\ \cancel{mol\ Na_2CO_3}}{1\ \cancel{mol\ Ba(NO_3)_2}} \times \frac{105.99\ g\ Na_2CO_3}{1\ \cancel{mol\ Na_2CO_3}}$$

$$= 636\ mg \text{ or } 0.636\ g\ Na_2CO_3$$

10. $MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(\ell) + CO_2(g)$

$m = 1.62$ g $\quad V = ?$ L

$M = 84.32$ g/mol $\quad c = 0.383$ mol/L

$$V\text{HCl} = 1.62 \text{ g } \cancel{MgCO_3} \times \frac{1 \text{ } \cancel{\text{mol } MgCO_3}}{84.32 \text{ } \cancel{\text{g } MgCO_3}} \times \frac{2 \text{ } \cancel{\text{mol HCl}}}{1 \text{ } \cancel{\text{mol } MgCO_3}} \times \frac{1 \text{ L}}{0.383 \text{ } \cancel{\text{mol HCl}}}$$

$$= 0.100 \text{ L}$$

11. $2Na_2S_2O_3(aq) + Cl_2(aq) \rightarrow 2NaCl(aq) + Na_2S_4O_6(aq)$

$V = ?$ L $\quad V = 54$ L

$c = 0.170$ mol/L $\quad c = 2.8 \times 10^{-5}$ mol/L

$$V\text{Na}_2\text{S}_2\text{O}_3 = 54 \text{ L} \times \frac{2.8 \times 10^{-5} \text{ } \cancel{\text{mol } Cl_2}}{1 \text{ L}} \times \frac{2 \text{ } \cancel{\text{mol } Na_2S_2O_3}}{1 \text{ } \cancel{\text{mol } Cl_2}} \times \frac{1 \text{ L}}{0.170 \text{ } \cancel{\text{mol } Na_2S_2O_3}}$$

$$= 18 \text{ mL or } 0.018 \text{ L}$$

12. $Na_2SO_4(aq) + Pb(NO_3)_2(aq) \rightarrow PbSO_4(s) + 2NaNO_3(aq)$

$V = ?$ L $\quad V = 100$ mL

$c = 0.150$ mol/L $\quad c = 0.100$ mol/L

$$V\text{Na}_2\text{SO}_4 = 100 \text{ mL} \times \frac{0.100 \text{ } \cancel{\text{mol } Pb(NO_3)_2}}{1 \text{ } \cancel{\text{mL}}} \times \frac{1 \text{ } \cancel{\text{mol } Na_2SO_4}}{1 \text{ } \cancel{\text{mol } Pb(NO_3)_2}} \times \frac{1 \text{ } \cancel{\text{mL}}}{0.150 \text{ } \cancel{\text{mol } Na_2SO_4}}$$

$$= 66.7 \text{ mL or } 0.0667 \text{ L}$$

13. $Sr(OH)_2(aq) + 2CH_3COOH(aq) \rightarrow Sr(CH_3COO)_2(aq) + 2\,H_2O(l)$

$V = ?$ L $\quad V = 5.00$ mL

$c = 0.100$ mol/L $\quad c = 0.833$ mol/L

$$V\text{Sr(OH)}_2 = 5.00\text{ mL} \times \frac{0.100\ \cancel{\text{mol CH}_3\text{COOH}}}{1\ \cancel{\text{L}}} \times \frac{1\ \cancel{\text{mol Sr(OH)}_2}}{2\ \cancel{\text{mol CH}_3\text{COOH}}} \times \frac{1\ \cancel{\text{L}}}{0.150\ \cancel{\text{mol Sr(OH)}_2}}$$

$$= 20.8\text{ mL}$$

14. $3NO_2(g) + H_2O(\ell) \rightarrow 2HNO_3(aq) + NO(g)$

$n = 2.31 \times 10^4$ mol $\quad V = ?$ L

$c = 15.4$ mol/L

$$V\text{HNO}_3 = 2.31 \times 10^4\ \cancel{\text{mol NO}_2} \times \frac{2\ \cancel{\text{mol HNO}_3}}{3\ \cancel{\text{mol NO}_2}} \times \frac{1\text{ L}}{15.4\ \cancel{\text{mol HNO}_3}}$$

$$= 1.00 \times 10^3\text{ L}$$

15. $C_2H_5OH(aq) + O_2(g) \rightarrow CH_3COOH(aq) + H_2O(\ell)$

$m = 6.00$ g $\quad V = 1.00$L

$M = 46.08$ g/mol $\quad c = ?$ mol/L

$$c\,\text{CH}_3\text{COOH} = 6.00\ \cancel{\text{g C}_2\text{H}_5\text{OH}} \times \frac{1\ \cancel{\text{mol C}_2\text{H}_5\text{OH}}}{46.08\ \cancel{\text{g C}_2\text{H}_5\text{OH}}} \times \frac{1\text{ mol CH}_3\text{COOH}}{1\ \cancel{\text{mol C}_2\text{H}_5\text{OH}}} \times \frac{1}{1.00\text{ L}}$$

$$= 0.130\text{ mol/L}$$

16. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

$V = 2.00$ L $\quad V = ?$ L

$$V\text{HCl} = 2.00\ \cancel{\text{L H}_2} \times \frac{2\text{ L HCl}}{1\ \cancel{\text{L H}_2}} = 4.00\text{ L HCl}$$

17. $v_{\text{Total}} = 4.00 \text{ mol } C_3H_5(NO_3)_2 \times \dfrac{29 \text{ mol gas}}{4 \text{ mol } C_3H_5(NO_3)_2} \times \dfrac{24.8 \text{ L}}{1 \text{ mol gas}}$

$= 719 \text{ L}$

18. $2NI_3(s) \rightarrow N_2(g) + 3I_2(g)$

$m = 395 \text{ mg}$ $V = ? \text{ L}$ $V = ? \text{ L}$

$M = 394.71 \text{ g/mol}$

$V N_2 = 395 \text{ mg } NI_3 \times \dfrac{1 \text{ mol } NI_3}{394.71 \text{ g } NI_3} \times \dfrac{1 \text{ mol } N_2}{2 \text{ mol } NI_3} \times \dfrac{22.4 \text{ L}}{1 \text{ mol } N_2}$

$= 10.1 \text{ mL}$

$V I_2 = 395 \text{ mg } NI_3 \times \dfrac{1 \text{ mol } NI_3}{394.71 \text{ g } NI_3} \times \dfrac{3 \text{ mol } I_2}{2 \text{ mol } NI_3} \times \dfrac{22.4 \text{ L}}{1 \text{ mol } I_2}$

$= 44.8 \text{ mL}$

19. $MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + 2H_2O(\ell) + Cl_2(g)$

$m = 0.250 \text{ g}$ $V = 100 \text{ mL}$ $V = ? \text{ L}$

$M = 86.94$ g/mol $c = 0.104$ mol/L

If the MnO_2 is limiting

$$m\,Cl_2 = 0.250\ \text{g}\ \cancel{MnO_2} \times \frac{1\ \cancel{\text{mol}\ MnO_2}}{86.94\ \cancel{\text{g}\ MnO_2}} \times \frac{1\ \cancel{\text{mol}\ Cl_2}}{1\ \cancel{\text{mol}\ MnO_2}} \times \frac{24.8\ \text{L}}{1\ \cancel{\text{mol}\ Cl_2}}$$

$$= 0.0713\ \text{L}$$

If the HCl is limiting

$$m\,Cl_2 = 0.100\ \cancel{L} \times \frac{0.104\ \cancel{\text{mol HCl}}}{1\ \cancel{L}} \times \frac{1\ \cancel{\text{mol}\ Cl_2}}{4\ \cancel{\text{mol HCl}}} \times \frac{24.8\ \text{L}}{1\ \cancel{\text{mol}\ Cl_2}}$$

$$= 0.0645\ \text{L}$$

Since the HCl(aq) would produce the least amount of product, it is the limiting reactant and the volume of gas to be collected will be 0.0645 L.

20. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(\ell)$

If the C_2H_6 is limiting

$$V\,CO_2 = 2.00\ \cancel{\text{L}\ C_2H_6} \times \frac{4\ \text{L}\ \cancel{CO_2}}{2\ \cancel{\text{L}\ C_2H_6}} = 4.00\ \text{L}$$

If the O_2 is limiting

$$V\,CO_2 = 2.00\ \cancel{\text{L}\ O_2} \times \frac{4\ \text{L}\ CO_2}{7\ \cancel{\text{L}\ O_2}} = 1.14\ \text{L}$$

Since the $O_2(g)$ produces the least amount of product, it is the limiting reactant and the volume of gas to be collected will be 1.14 L.

Chapter 7 Review Answers

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Answers to Understanding Concepts Questions

1. A complete balanced equation shows all the reactants and products as if they were intact compounds that do not dissociate in solution. An ionic equation is a more accurate representation of a reaction in solution, because it shows all the high-solubility ionic compounds dissociated into ions. A net ionic equation shows only the actual chemical change that occurs.
2. A specific colour is emitted when thermally excited electrons from a heated metal ion emit energy as visible light as they move back down to lower energy levels within the ion.
3. To determine the mole ratio of two compounds in a reaction, use the coefficients in the balanced chemical equation.
4. A stoichiometric calculation would be important to chemical engineers trying to determine the masses of liquid hydrogen, liquid oxygen, and solid fuel needed for launching a space shuttle.
5. Gravimetric stoichiometry calculations determine the mass of one component based on the mass of another component in a reaction equation. Solution stoichiometry calculations determine the concentration, volume, or mass of one component based on the concentration or volume of another component in the solution. Gas stoichiometry calculations use the volumes, temperatures, and pressures of gaseous reactants or products to determine the amount of other reactants or products in a reaction equation.

Answers to Applying Concepts Questions

6. **(a)** $MnO_4^-(aq)$

(b) $Ni^{2+}(aq)$

(c) $Na^+(aq)$

(d) $Cu^{2+}(aq)$

7. **(a)** $3Ba^{2+}(aq) + 2BO_3^{2-}(aq) \rightarrow Ba_3(BO_3)_2(s)$

(b) $Cr(s) + 2Ag^+(aq) \rightarrow Cr^{2+}(aq) + 2Ag(s)$

(c) $2Al(s) + 3Zn^{2+}(aq) \rightarrow 3Zn(s) + 2Al^{3+}(aq)$

(d) $Br_2(\ell) + 2I^-(aq) \rightarrow I_2(s) + 2Br^-(aq)$

(e) $H^+(aq) + HSO_4^-(aq) + Sr^{2+}(aq) + 2OH^-(aq) \rightarrow SrSO_4(s) + 2H_2O(\ell)$

8. $Cu(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow 2NaNO_3(aq) + CuSO_4(s)$

The spectator ions are $Na^+(aq)$ and $NO_3^-(aq)$. They are identified as the two ions that are present in aqueous form on both sides of the reaction. Or, a total ionic equation may be written. When this equation is written, the spectator ions are in the same form on both the reactant and product sides of the equation (their states do not change), as shown below:

Net ionic equation: $Cu^{2+}(aq) + SO_4^{2-} \rightarrow CuSO_4(s)$

9. The only ions that produce a pink solution are $Co^{2+}(aq)$ and $Mn^{2+}(aq)$, while the ions that produce a green solution are $Cr^{3+}(aq)$, $Cu^+(aq)$, $Fe^{2+}(aq)$ and $Ni^{2+}(aq)$. To produce a precipitate that leaves a pink solution, the anion must be insoluble with the cation producing the green solution, while being soluble with the cation that produces the pink solution. Using the data available in the solubility chart, one such combination would be $CoCl_2(aq)$ or $MnCl_2(aq)$ (or $CoBr_2(aq)$, $MnBr_2(aq)$, $CoI_2(aq)$ or $MnI_2(aq)$ mixed with $CuNO_3(aq)$). An example of the reaction that takes place is shown below:

$CoCl_2(aq) + 2CuNO_3(aq) \rightarrow Co(NO_3)_2(aq) + 2CuCl(s)$

pink green pink precipitate

10. Once the solid is dissolved, use a flame test to attempt to identify the cation. If the flame is red, it could be strontium ion. Add a few drops of aqueous sodium sulfate to the solution. Strontium ions and sulfate ions will form insoluble strontium sulfate. As well, a solution of strontium ions will be colourless.

11. To solve a gas stoichiometry problem, you would need the pressure and the temperature at which the reaction takes place in addition to the mass of the beryllium that reacts.

Answers to Solving Problems Questions

12. (a) 2 mol $H_2(g)$:1 mol $CO(g)$:1 mol $CH_3OH(g)$

(b) $$n\mathrm{H_2} = 130\ \text{kmol}\ \mathrm{CH_3OH} \times \frac{2\ \text{mol}\ \mathrm{H_2}}{1\ \text{mol}\ \mathrm{CH_3OH}}$$
$$= 260\ \text{kmol}\ \mathrm{H_2}$$

260 kmol of hydrogen is required.

(c) $$\mathrm{nH_2} = 6.00\ \text{mol}\ \mathrm{CO} \times \frac{2\ \text{mol}\ \mathrm{H_2}}{1\ \text{mol}\ \mathrm{CO}} = 12.0\ \text{mol}\ \mathrm{H_2}$$

12.0 mol of hydrogen is required.

13. (a) 2 mol $C_4H_{10}(g)$: 13 mol $O_2(g)$: 8 mol $CO_2(g)$: 10 mol $H_2O(g)$

(b) $$n\mathrm{O_2} = 8.0\ \text{mol}\ \mathrm{C_4H_{10}} \times \frac{13\ \text{mol}\ \mathrm{O_2}}{2\ \text{mol}\ \mathrm{C_4H_{10}}}$$
$$= 52\ \text{mol}\ \mathrm{O_2}$$

52 mol of oxygen is required.

(c) $$\mathrm{nH_2O} = 3.50\ \text{mol}\ \mathrm{C_4H_{10}} \times \frac{10\ \text{mol}\ \mathrm{H_2O}}{2\ \text{mol}\ \mathrm{C_4H_{10}}}$$
$$= 17.5\ \text{mol}\ \mathrm{H_2O}$$

17.5 mol of water vapour is produced.

14. $2\,Mg(s) + O_2(g) \rightarrow 2MgO(s)$

$m = 50$ g $\qquad m = ?$ g

$M = 24.31$ g/mol $\qquad M = 40.31$ g/mol

$$m\text{MgO} = 50\ \cancel{\text{g Mg}} \times \frac{1\ \cancel{\text{mol Mg}}}{24.31\ \cancel{\text{g Mg}}} \times \frac{1\ \cancel{\text{mol MgO}}}{1\ \cancel{\text{mol Mg}}} \times \frac{40.31\ \text{g MgO}}{1\ \cancel{\text{mol MgO}}}$$

$$= 83\ \text{g}$$

83 g of metal oxide is formed.

15. $Cl_2(g) + Na(s) \rightarrow 2NaCl(s)$

$m = 4.6$ g $\qquad m = ?$ g

$M = 22.99$ g/mol $\qquad M = 58.44$ g/mol

$$m\text{NaCl} = 4.6\ \cancel{\text{g Na}} \times \frac{1\ \cancel{\text{mol Na}}}{22.99\ \cancel{\text{g Na}}} \times \frac{2\ \cancel{\text{mol NaCl}}}{1\ \cancel{\text{mol Na}}} \times \frac{58.44\ \text{g NaCl}}{1\ \cancel{\text{mol NaCl}}}$$

$$= 12\ \text{g}$$

12 g of white solid is expected.

16. $2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

$m = 72.1$ g $\qquad m = ?$ g

$M = 114.26$ g/mol $\qquad M = 44.01$ g/mol

$$m\text{CO}_2 = 72.1\ \cancel{\text{g } C_8H_{18}} \times \frac{1\ \cancel{\text{mol } C_8H_{18}}}{114.26\ \cancel{\text{g } C_8H_{18}}} \times \frac{16\ \cancel{\text{mol CO}_2}}{2\ \cancel{\text{mol } C_8H_{18}}} \times \frac{44.01\ \text{g CO}_2}{1\ \cancel{\text{mol CO}_2}}$$

$$= 222\ \text{g}$$

222 g of carbon dioxide is expected.

17. $TiCl_4(\ell) + 2H_2O(\ell) \rightarrow TiO_2(s) + 4HCl(g)$

$m = 85.6$ g $\qquad m = ?$ g

$M = 189.67$ g/mol $\qquad M = 79.87$ g/mol

$$m\text{TiO}_2 = 85.6 \text{ g } \cancel{\text{TiCl}_4} \times \frac{1 \text{ } \cancel{\text{mol TiCl}_4}}{189.67 \text{ g } \cancel{\text{TiCl}_4}} \times \frac{1 \text{ mol } \cancel{\text{TiO}_2}}{1 \text{ } \cancel{\text{mol TiCl}_4}} \times \frac{79.87 \text{ g TiO}_2}{1 \text{ } \cancel{\text{mol TiO}_2}}$$

$$= 36.0 \text{ g}$$

36.0 g of titanium(IV) oxide is expected.

18. $3Ag_2S(s) + 2Al(s) \rightarrow 6Ag(s) + Al_2S_3(aq)$

$m = ?$ g $\qquad m = 6.4$ g

$M = 247.81$ g/mol $\qquad M = 107.87$ g/mol

$$m\text{Ag}_2\text{S} = 6.4 \text{ g } \cancel{\text{Ag}} \times \frac{1 \text{ } \cancel{\text{mol Ag}}}{107.87 \text{ g } \cancel{\text{Ag}}} \times \frac{3 \text{ } \cancel{\text{mol Ag}_2\text{S}}}{6 \text{ } \cancel{\text{mol Ag}}} \times \frac{247.81 \text{ g Ag}_2\text{S}}{1 \text{ } \cancel{\text{mol Ag}_2\text{S}}}$$

$$= 7.4 \text{ g}$$

7.4 g of tarnish is removed.

Answers to Making Connections Questions

19. (a) $Hg(NO_3)_2(aq) + Na_2S(aq) \rightarrow HgS(s) + 2NaNO_3(aq)$

$Hg^{2+}(aq) + S^{2-}(aq) \rightarrow HgS(s)$

(b) The reaction of mercury(II) nitrate with sodium sulfide can be used to remove mercury(II) ions from the waste water because of the formation of solid mercury(II) sulfide. The solid precipitate can then be filtered to separate the mercury from the waste water.

(c) Mercury(II) nitrate is more of an environmental concern because it is soluble in water and can be ingested by marine species and carried up through the food chain (biomagnification) more easily than solid mercury(II) sulfide.

(d) We are making the assumption that both sodium sulfide and sodium nitrate are less toxic to the environment than either mercury(II) nitrate or mercury(II) sulfide.

(e) $Hg(NO_3)_2(aq) + Na_2S(aq) \rightarrow HgS(s) + 2NaNO_3(aq)$

$m = 300$ g $\quad m = ?$ g

$M = 324.61$ g/mol $\quad M = 78.05$ g/mol

$$m Na_2S = 300 \text{ g } \cancel{Hg(NO_3)_2} \times \frac{1 \text{ } \cancel{\text{mol } Hg(NO_3)_2}}{324.61 \text{ g } \cancel{Hg(NO_3)_2}} \times \frac{1 \text{ } \cancel{\text{mol } Na_2S}}{1 \text{ } \cancel{\text{mol } Hg(NO_3)_2}} \times \frac{78.05 \text{ g } Na_2S}{1 \text{ } \cancel{\text{mol } Na_2S}}$$

$$= 72.1 \text{ g}$$

72.1 g sodium sulfide will be required.

20. Sample Procedure:

1. Observe the solution colour. The solution that appears blue-green will be the $NiSO_4(aq)$, and the remaining four will be colourless.
2. To an aliquot of each of the four colourless solutions, add one drop of $NaCl(aq)$. The solution that forms a precipitate will be $AgNO_3(aq)$.
3. To an aliquot of each of the remaining three solutions, add one drop of Na_2SO_4. The solution that forms a precipitate will be $CaCl_2(aq)$.

4. Perform a flame test on an aliquot of the remaining two solutions. The solution that produces a red flame is LiOH(aq).
5. The remaining solution is $NH_4Cl(aq)$.

Sample Evidence Table

Solution identity	Solution colour	Addition of NaCl(aq)	Addition of $Na_2SO_4(aq)$	Flame colour
$CaCl_2(aq)$	colourless	no precipitate	precipitate	N/A
$NiSO_4(aq)$	blue-green	N/A	N/A	N/A
$AgNO_3(aq)$	colourless	precipitate	N/A	N/A
LiOH(aq)	colourless	no precipitate	no precipitate	red
$NH_4Cl(aq)$	colourless	no precipitate	no precipitate	colour

Students' may select other chemicals for the selective precipitation. Check the solubility table (Appendix G: Chemistry Data Tables in the student textbook: Table G.9 p. 782) to ensure the correct precipitation patterns. Students may also try to use litmus paper to differentiate the LiOH(aq) (a base) from $NH_4Cl(aq)$ (they will predict neutral). They will not be able to predict that ammonium chloride is an acid until *Chemistry 30*.

21. (a) $10NaN_3(s) + 2KNO_3(s) + 6SiO_2(s) \rightarrow K_2SiO_3(s) + 5Na_2SiO_3(s) + 16N_2(g)$

$m = ?\ g$ $\quad V = 60.0\ L$

$M = 65.02\ g/mol$ $\quad T = 303\ K$

$P = 115\ kPa$

$$m\,NaN_3 = \frac{115\ \cancel{kPa} \times 60.0\ \cancel{L}}{8.314\ \cancel{kPa}\cdot\cancel{L}/\cancel{mol}\cdot\cancel{K} \times 303\ \cancel{K}} \times \frac{10\ \cancel{mol\ NaN_3}}{16\ \cancel{mol\ N_2}} \times \frac{65.02\ g\ \cancel{NaN_3}}{1\ \cancel{mol\ NaN_3}}$$

$$= 111\ g$$

(b) If there was not an excess amount of potassium nitrate and silicon dioxide, the $NaN_3(s)$ would react to form sodium metal.

(c) Testing the safety of reactions is important because it ensures that they are safe and people who use the final product will be unharmed. Safety testing can also help predict where reactions can go wrong if the system needs to be redesigned.

22. (a) $4KO_2(s) + 2CO_2(g) \rightarrow 2K_2CO_3(s) + 3O_2(g)$

$m = ?\ g$ $\quad v = 50.0\ L$

$M = 71.10\ \frac{g}{mol}$ $\quad T = 295\ K$

$P = 101.3\ kPa$

$$mKO = \frac{101.3\ \cancel{kPa} \times 50.0\ \cancel{L}}{8.314\ \cancel{kPa}\cdot\cancel{L}/\cancel{mol}\cdot} \times \frac{4\ \cancel{mol\ KO_2}}{\cancel{K} \times 295\ \cancel{K}} \times \frac{71.10\ g\ \cancel{KO_2}}{2\ \cancel{mol\ CO_2}\ 1\ \cancel{mol\ KO_2}}$$

$$= 294\ g$$

(b) The potassium superoxide reaction also produces oxygen that is required by the astronauts in the space vehicle.